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Image Analysis via Soft Computing: Prototype Applications at NASA KSC and Product Commercialization.

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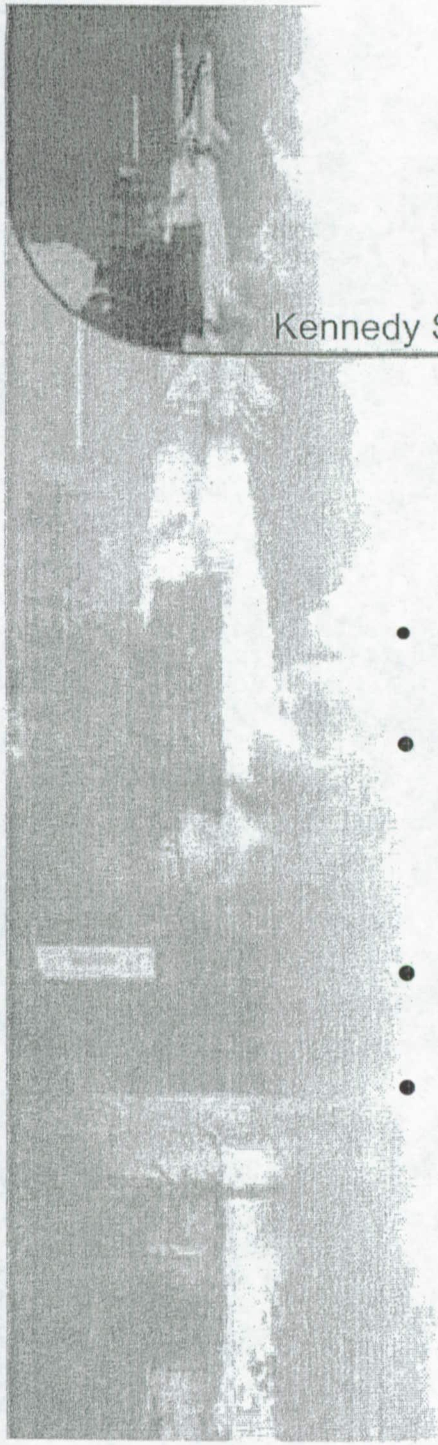
ASRC Aerospace Corp.

Jesus A. Dominguez
Steve Klinko

photo: NASA/Pat McCracken



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Outline

- System Development.
- Performance results compared with existing approaches.
- NASA applications.
- Commercialization.

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System Development

Soft Computing (SC):

differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation.

provides flexible information processing to handle real life ambiguous situations and achieve tractability, robustness, low solution cost, and <u>close resemblance of human decision making</u>.

System Development

- <u>*FRED (Fuzzy Reasoning Edge Detection):*</u>

  Image edge extraction technique developed at KSC (patent protected).

- <u>*FRAT (Fuzzy Reasoning Adaptive Thresholding):*</u>

  Image binarization technique developed at KSC (patent protected).

- <u>*Set of Image Enhancement Techniques:*</u>

  Techniques developed at KSC (one patent protected).

- <u>*Visual/Pattern Recognition:*</u>

  Commercially available technique (NeuroShell) via Artificial Neural Network (ANN) and GA (Genetic Algorithm).

Software implementation.

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- *ANSI C Code.*
- *C Code currently "wrapped" and embedded into a portable I/O image operator created using WIT (Logical Vision, Inc.), a commercially available image processing software.*
- *Operator has one input (original image) and two outputs, the binarized image and the optimal threshold value.*
- *User interface needed in applications created via Microsoft Foundation Class (MFC).*

Software implementation (Cont).

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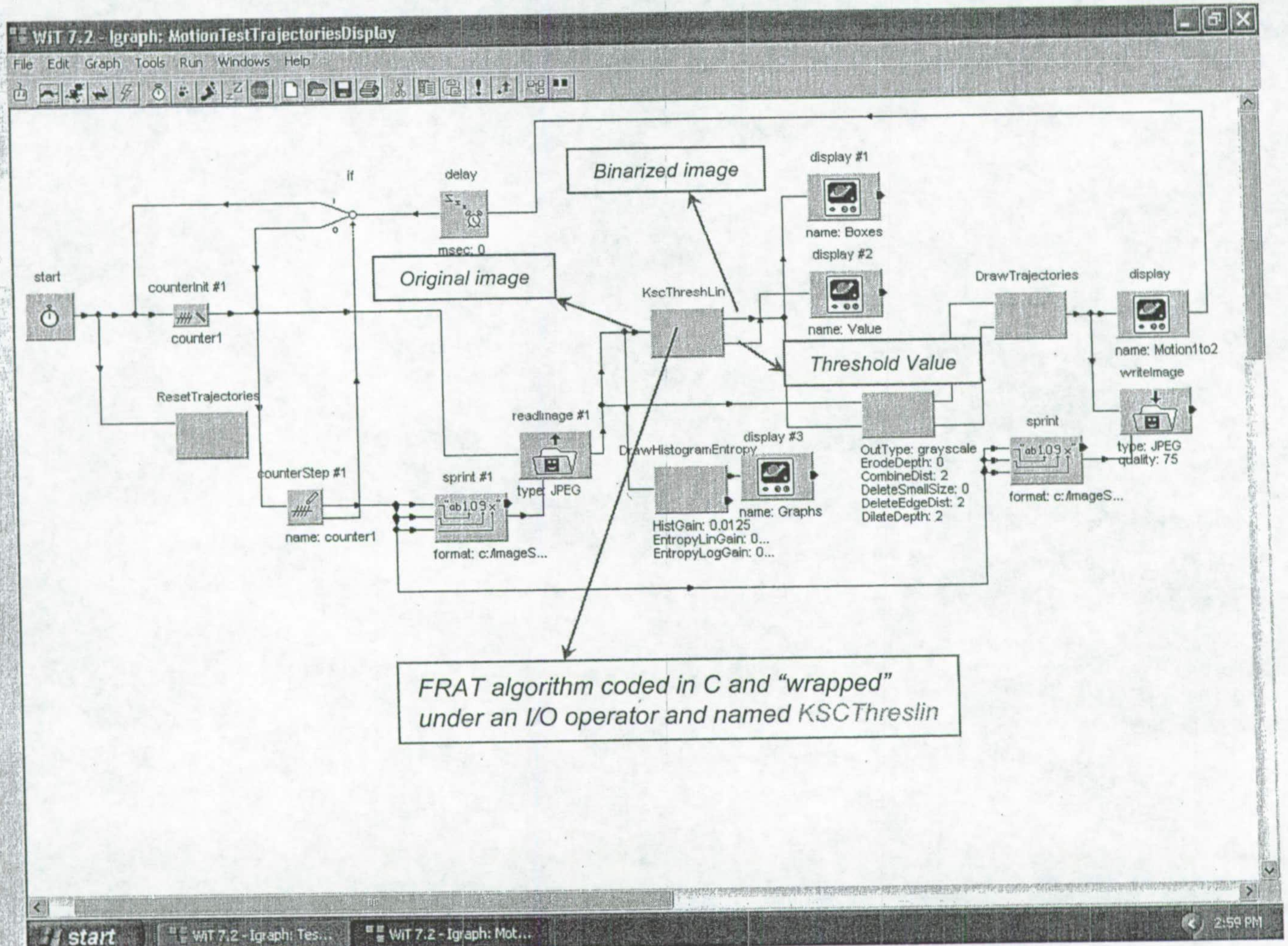

Performance results compared with existing approaches: FRED

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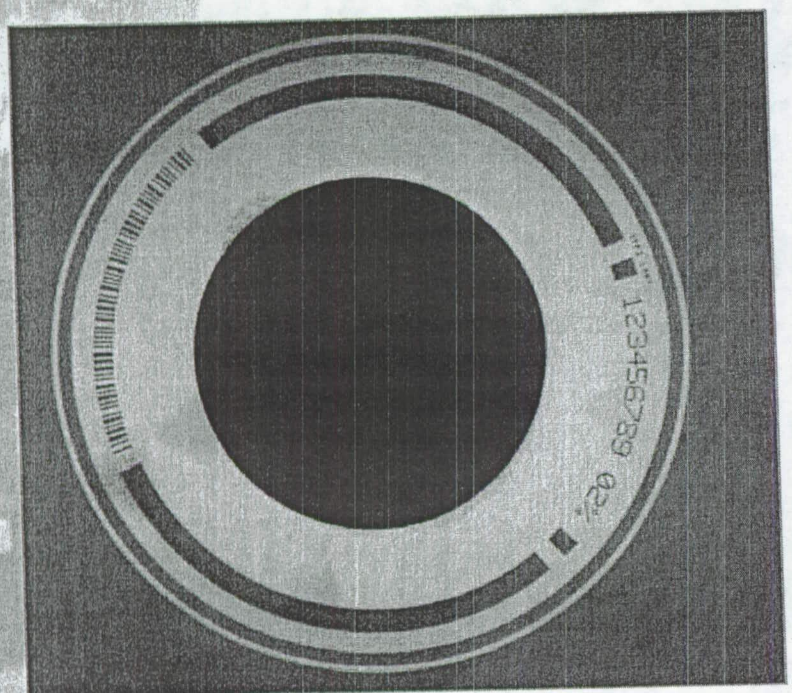
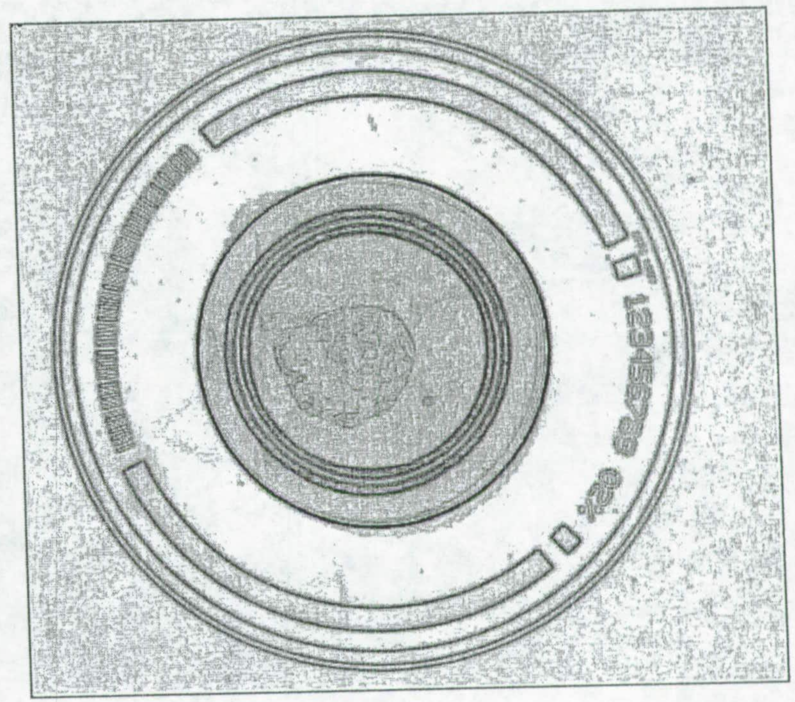


Original Image: CD containing a hard-to-see major scratch on the center



FRED: The major scratch is clearly shown as well as other minor ones

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Performance results compared with existing approaches: FRED

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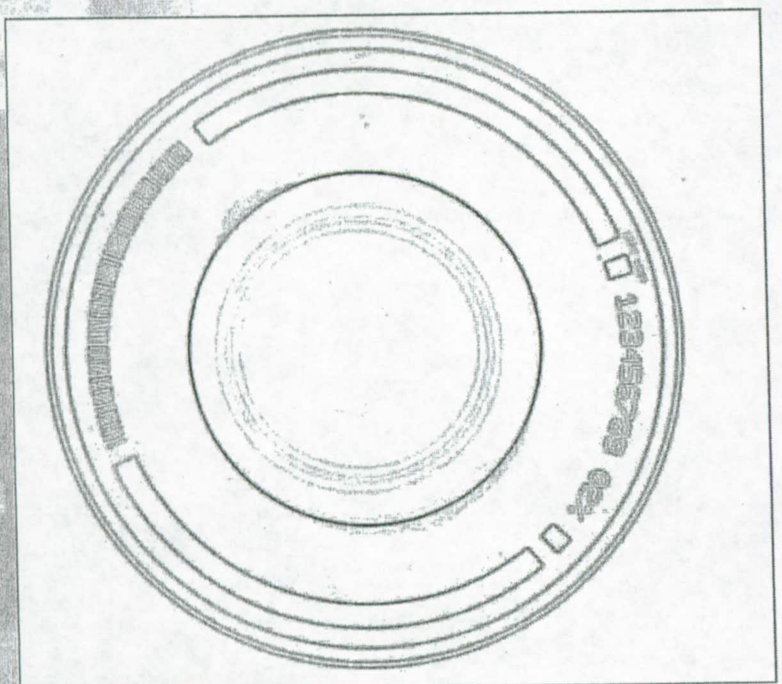

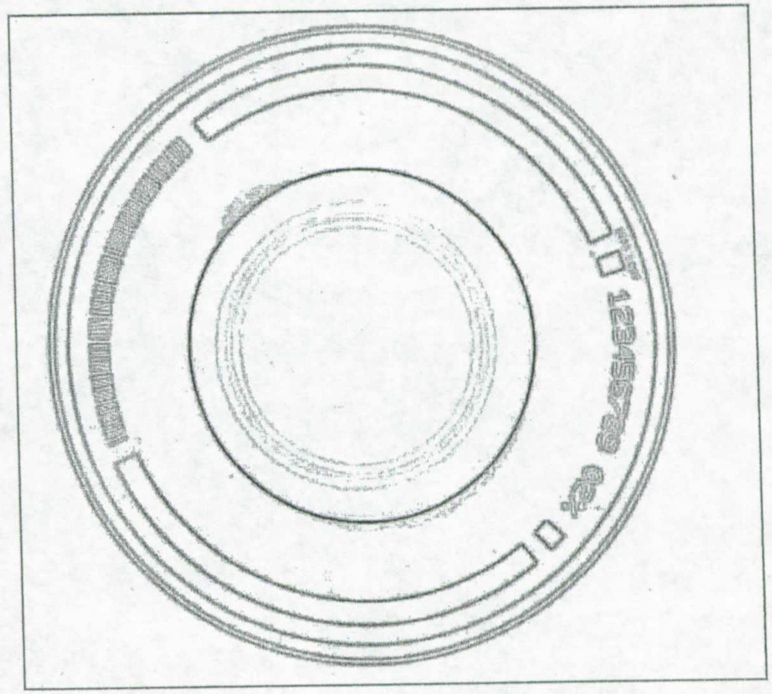

Sobel Approach: *less clear features, major scratch invisible*

Prewit Approach: *less clear feature- major scratch invisible*

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Performance results compared with existing approaches: FRAT

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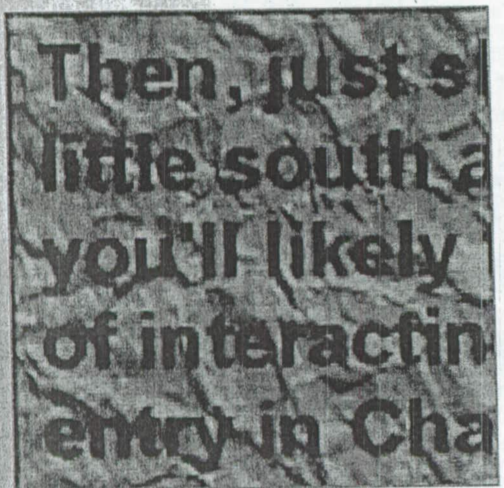
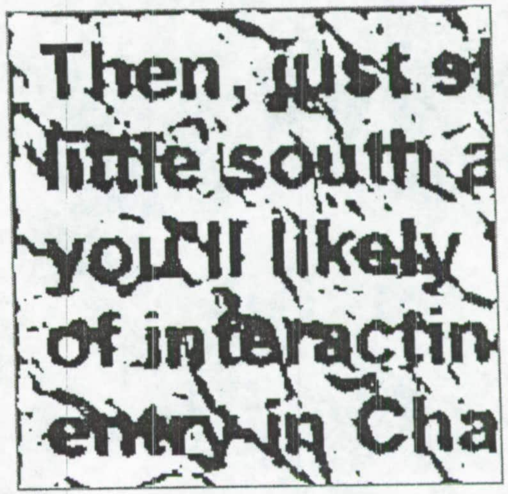
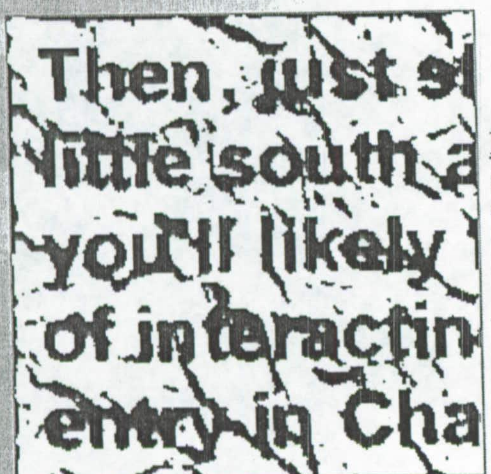


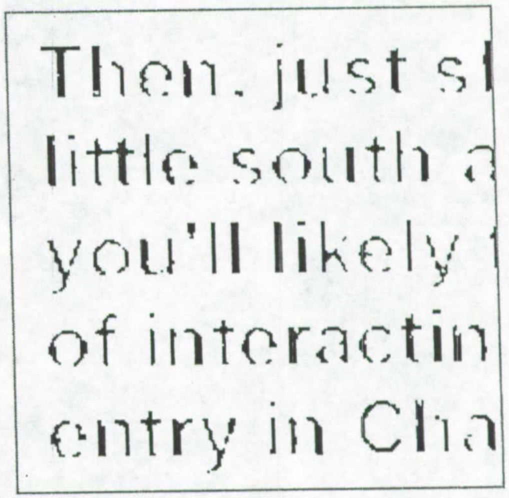
Original 8-bit Image
Size: 246×245



Otsu's Method
CPU time: 1.5 ms
Threshold: 88



Huang-Wang Method
CPU time: 10.8 ms
Threshold: 89



New Method
CPU time: 2.0 ms
Threshold: 8

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NASA Applications

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- *Real-Time (RT) Anomaly Detection.*
- *Real-Time (RT) Moving Debris Detection.*
- *Columbia Investigation.*

RT Anomaly Detection

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- <u>Image Preprocessing</u>.
  Enhancement
  Segmentation (Binarization) → FRAT

- <u>Classification and Learning Processes</u>.
  Artificial Neural Network (ANN)
  Genetic Algorithm (GA).

RT Anomaly Detection

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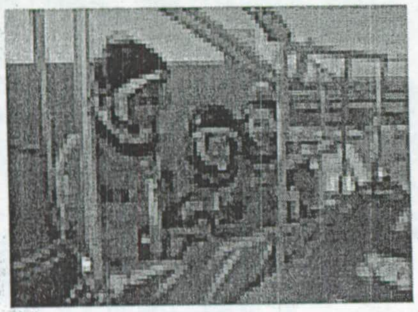
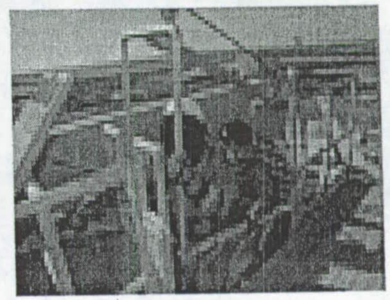
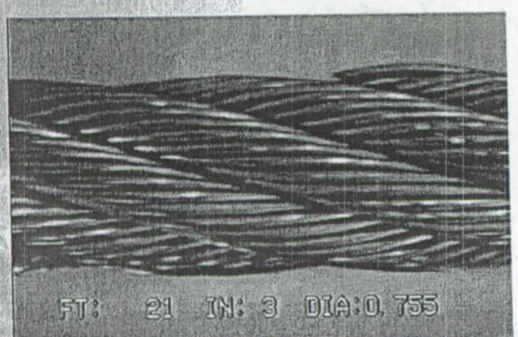
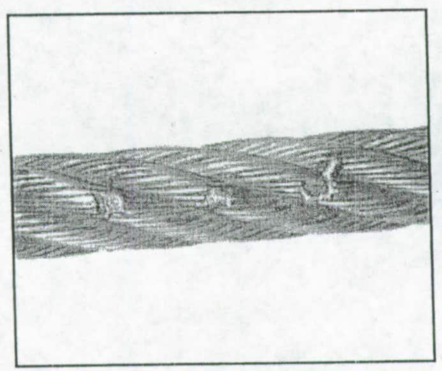
Astronauts training on the emergency egress system.

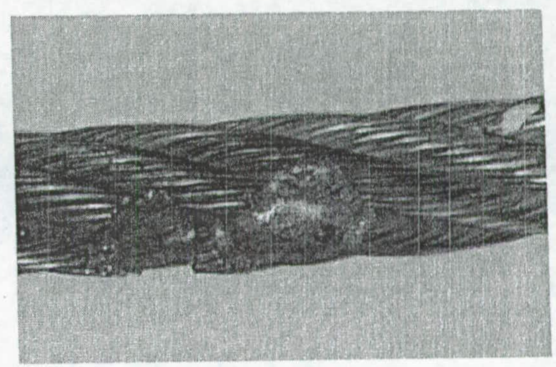




Anomalies on the basket slidewire







Broken strand.

Molten spots caused by lighting.

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RT Anomaly Detection (Cont.)

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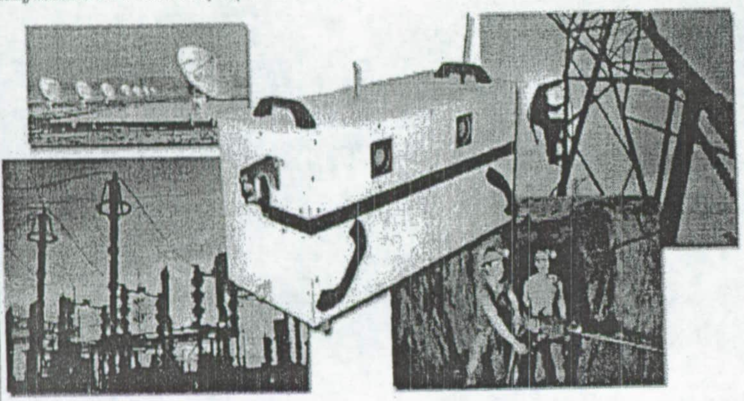
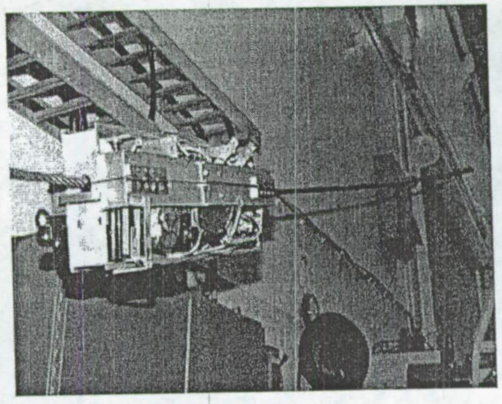
Cable and Line Inspection Mechanism (CLIM)

The National Aeronautics and Space Administration (NASA) seeks to transfer the NASA-developed Cable and Line Inspection Mechanism technology to private industry for use in commercial applications. This mechanism was developed at the John F. Kennedy Space Center (KSC) to provide a means for automated inspection of the seven slidewire cables used in the emergency egress system for the Space Shuttle. There are two sets of gantry cables plus an overhead lightning cable that require periodic inspection. These cables are nonferrous stainless steel; therefore, magnetic cable testers are not suitable for such inspections. Prior to this invention, cable inspections required 150 man-hours twice per year, with inspectors being hoisted in baskets to manually inspect the cables by direct touch and sight. The CLIM technology eliminates the hazardous, manpower-intensive, and time-consuming methods previously required to maintain the emergency egress system at peak performance standards. In addition, CLIM is capable of inspecting the top end of ferrous wire ropes near the attachment point in the cable housing where magnetic cable testers are unable to reach. CLIM has a further application with respect to radio frequency (RF) tower guy-wire inspections. The low-carbon, low-magnetic inductance of the stainless-steel guy-wire cables, combined with added RF radiation interference from the tower, yields magnetic cable testers ineffective. Therefore, CLIM's ability to conduct a 360-degree view of the cable without incurring RF radiation interference is significant.

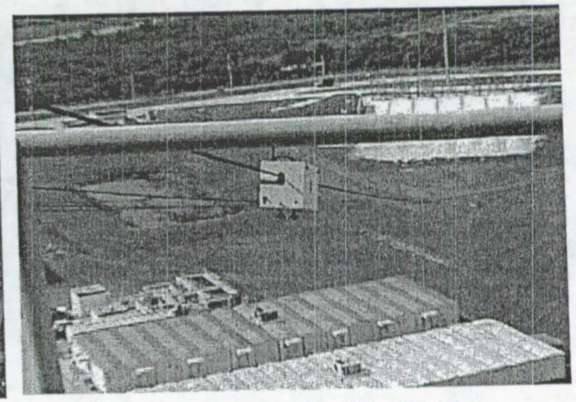


National Aeronautics and Space Administration
John F. Kennedy Space Center, FL

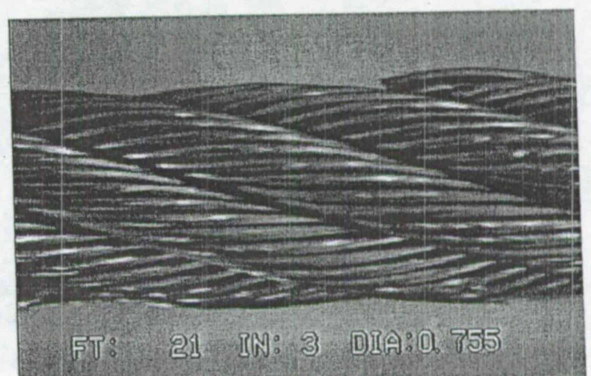
Cable & Line Inspection Mechanism (CLIM) built by NASA.



CLIM at the lab.



CLIM at the Shuttle Pad



Slidewire image acquired by CLIM

RT Anomaly Detection (Cont.)

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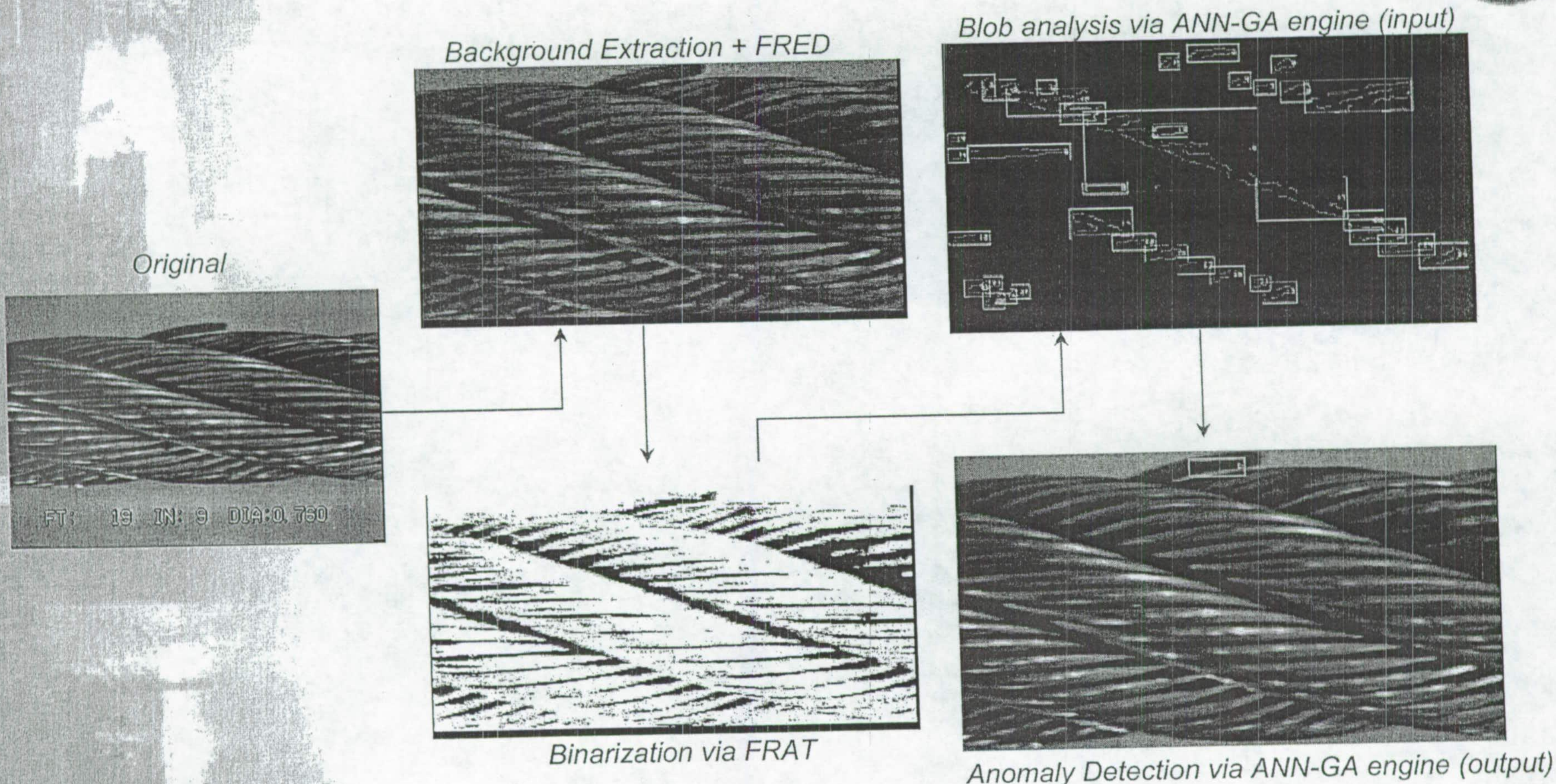

RT Anomaly Detection (Cont.)

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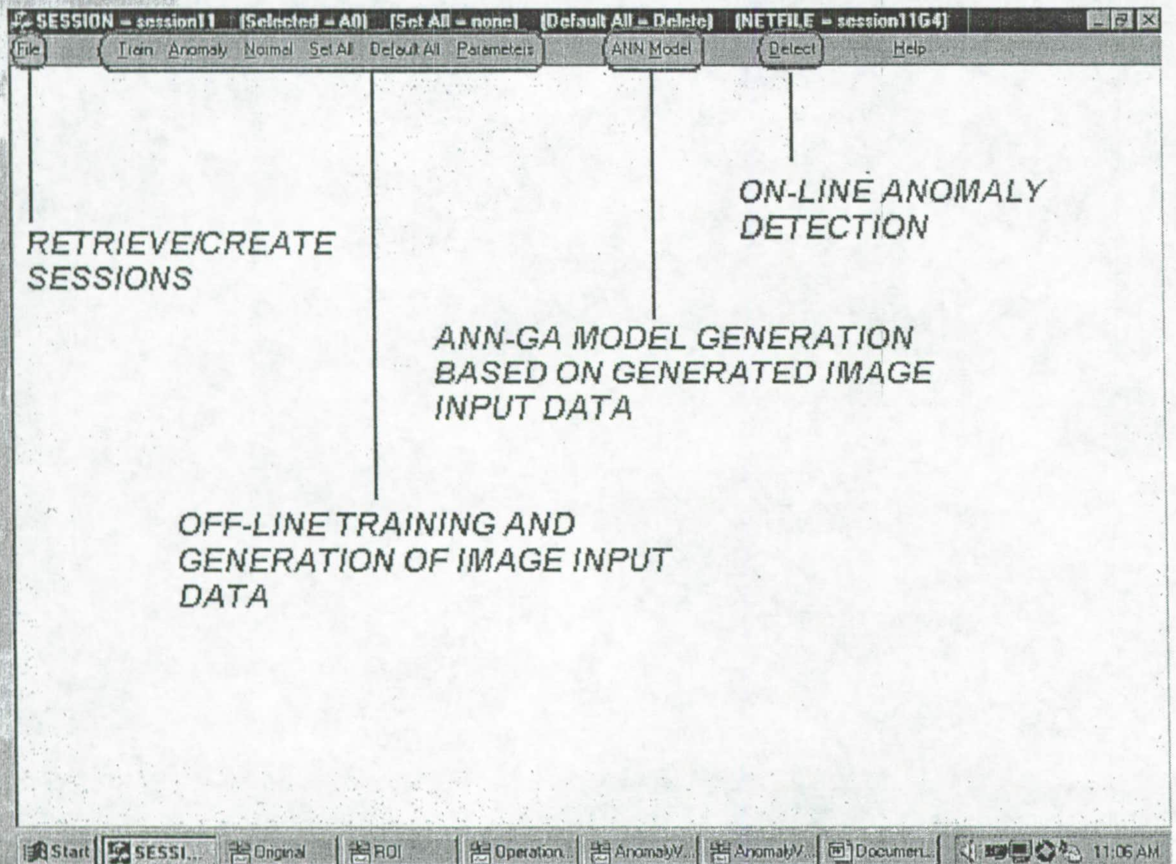

End-user front end built via MFC.

Main Menu

RT Anomaly Detection (Cont.)

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End-user front end built via MFC.

Training Stage.

RT Anomaly Detection (Cont.)

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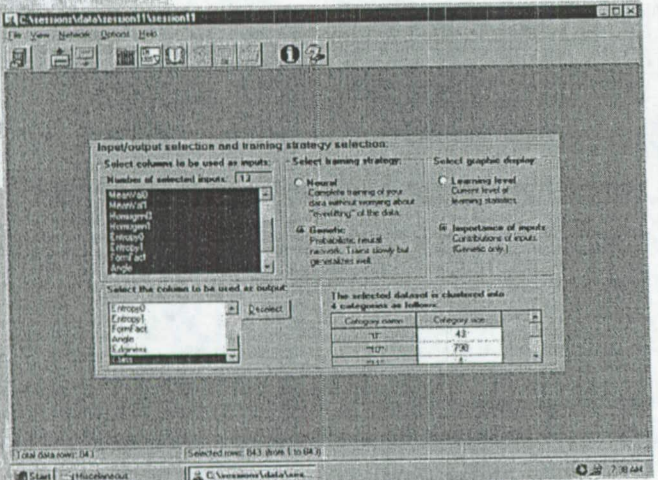

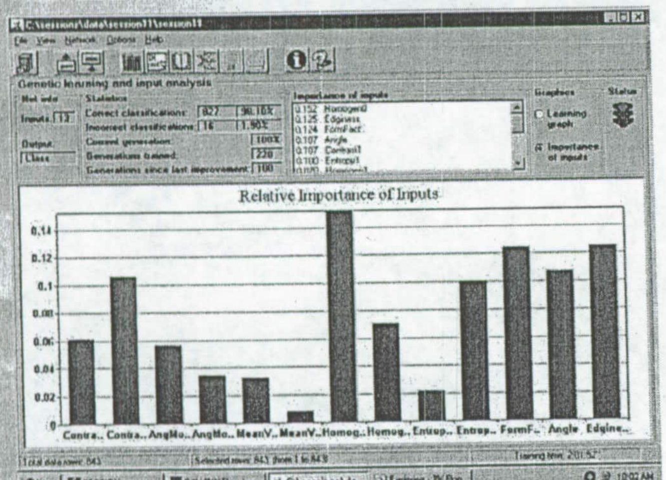

NeuroShell Classifier - Trained Network Information

Network filename: C:\sessions\data\session11\session11G3.net

The network was trained on:

Filename: C:\sessions\data\session11\session11.dat
Total data rows: 798
Training rows: 798
Start row: 1
End row: 798

Results of training session:

Training time: 1:20:16"
Generations trained: 178
Correct classifications: 98.87% (789 of 798)
Incorrect classifications: 1.13% (9 of 798)
Performance by category:
"0" 90.48% (38 of 42)
"10" 99.34% (751 of 756)

Network structure:

Training strategy: Genetic
Output name: "Class"
Number of inputs: 13
List of inputs and their relative importance:

"Contrast0"	0.006
"Contrast1"	0.163
"AngMom20"	0.074
"AngMom21"	0.018
"MeanVal0"	0.018
"MeanVal1"	0.074
"Homogen0"	0.095
"Homogen1"	0.045
"Entropy0"	0.184
"Entropy1"	0.01
"FormFact"	0.094
"Angle"	0.115
"Edginess"	0.106

Development of classification model via ANN & GA (NeuroShell)

RT Anomaly Detection (Cont.)

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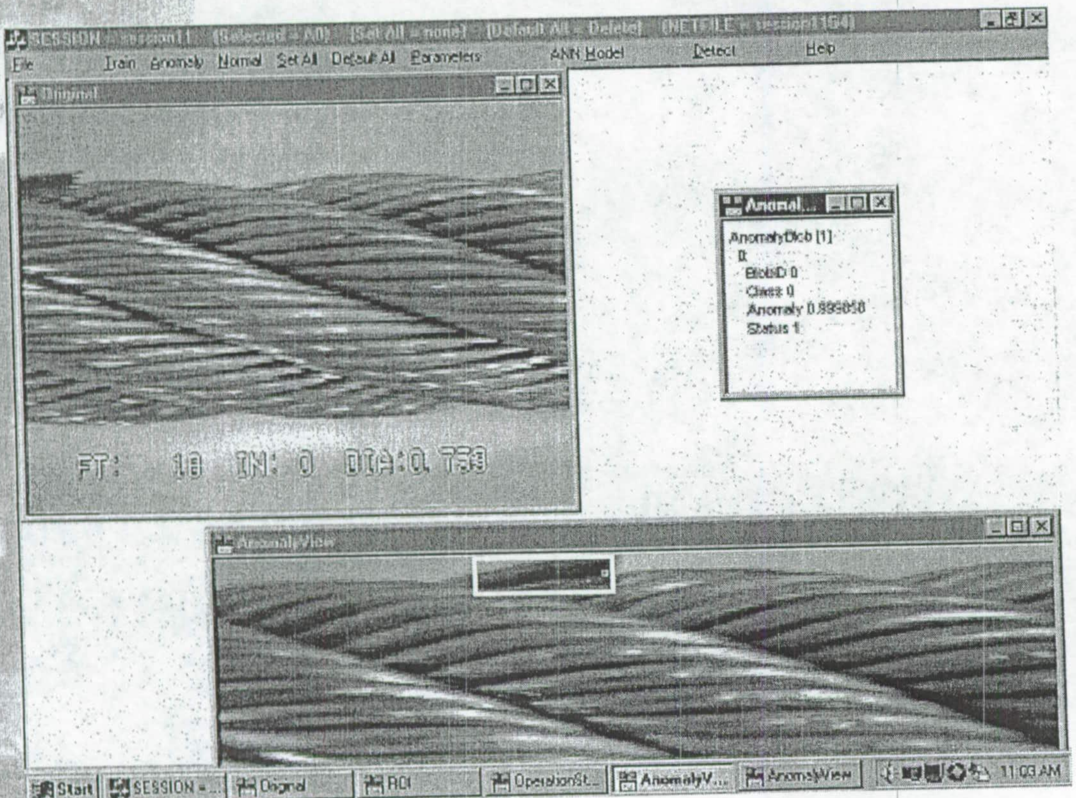

Anomaly Detected & displayed in RT.

Firing stage

RT Anomaly Detection (Cont.)

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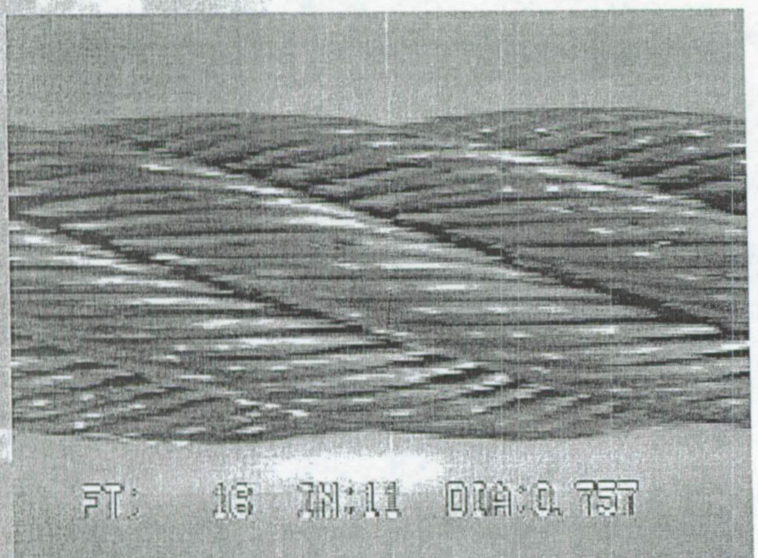
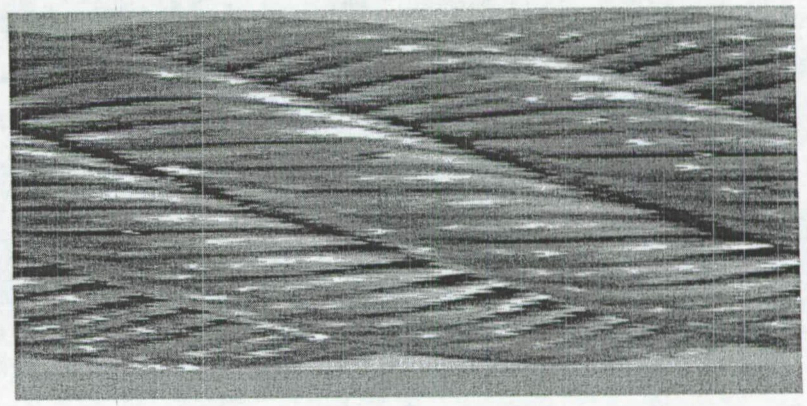


Original image acquired by CLIM



Automated Region of Interest (ROI) extraction and anomaly detection.

RT Moving FOD Detection

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- <u>Blob Generation (single image)</u>.
  Segmentation (Binarization) → FRAT

- <u>Blob/FOD Selection and Trajectory Computation</u>
  Logical path analysis (consecutive images).

RT Moving FOD Detection (Cont.)

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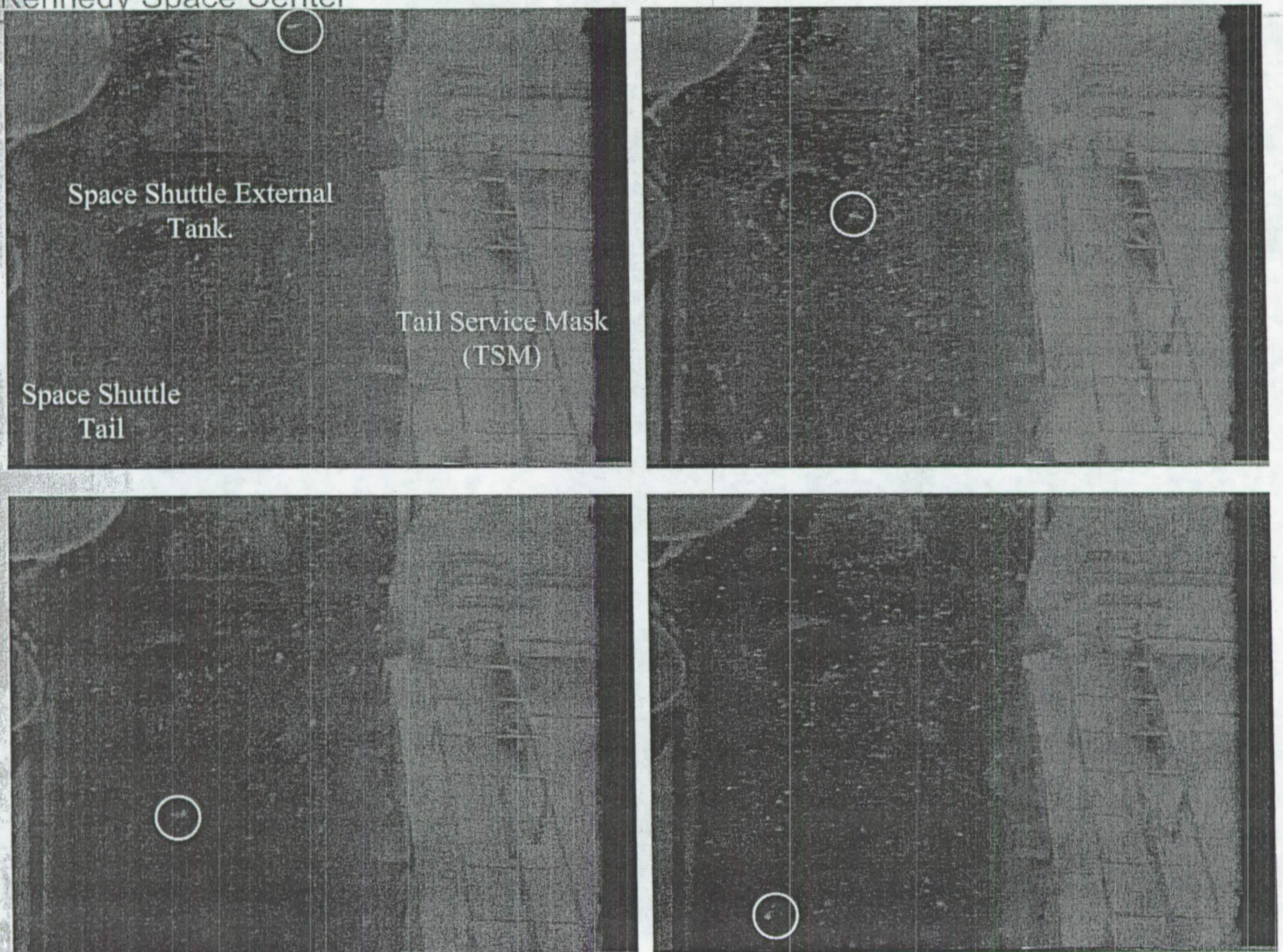

RT Moving FOD Detection (Cont.)

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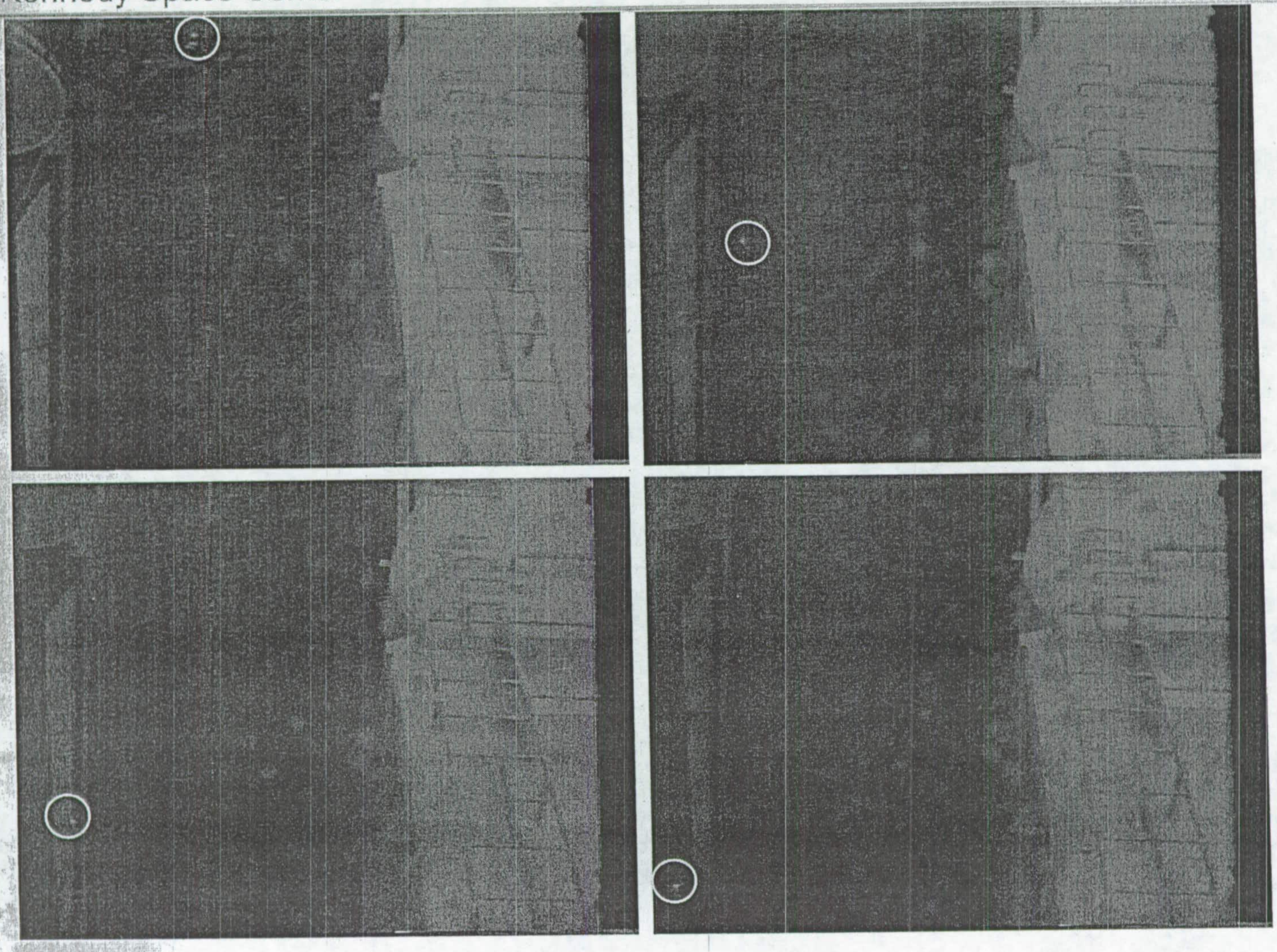

RT Moving FOD Detection (Cont.)

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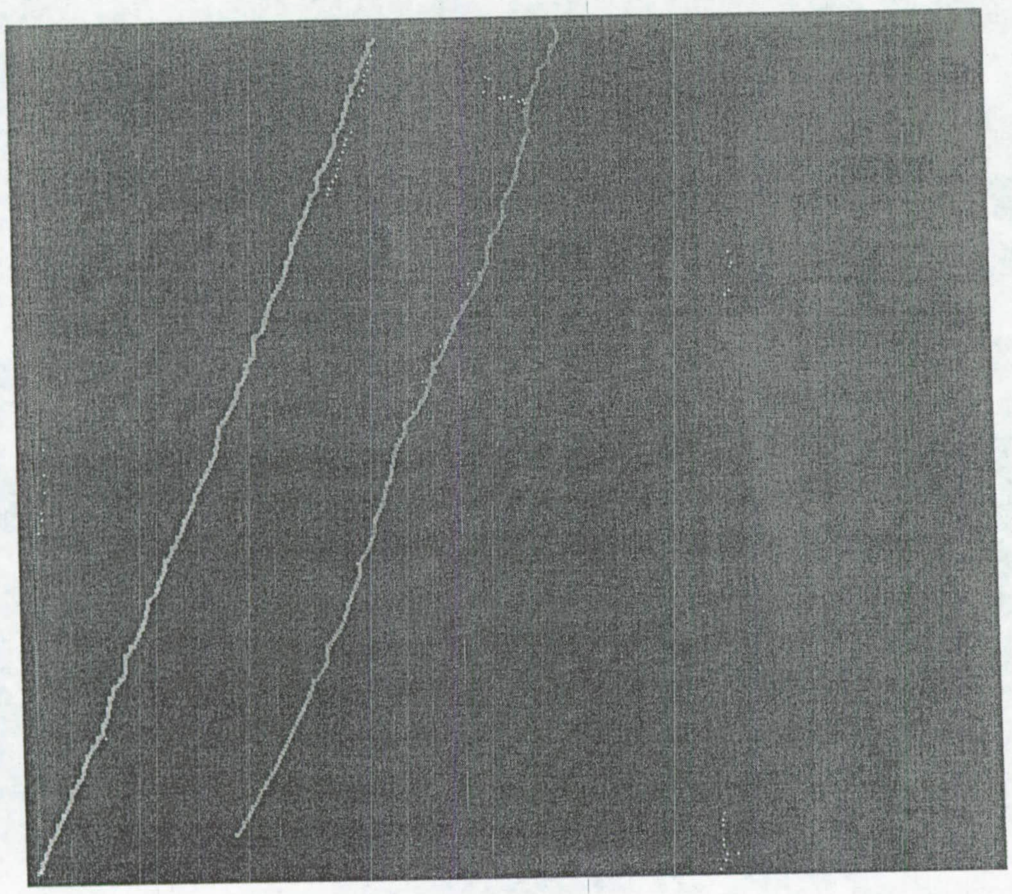

Foam Debris

- <u>2D: Detection & Location</u>.
  - Segmentation (Binarization)
  - Characterization (center of mass, borders, etc.)

$\boxed{\text{FRAT}}$

- <u>3D: Location & Trajectory</u>
  - Optimal path at three consecutive 3D projections.

Columbia Investigation

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STS-107 REPORT:

2D-Detection, 3D-Location & 3D-Velocity Estimation of Foam Debris Based on Images acquired by E212 & E208 Video Cameras.

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Jesus A. Dominguez, ASRC Aerospace Corp.

NASA Kennedy Space Center, June 12, 2003

Columbia Investigation: Foam Debris Detection/Location (Cont.)

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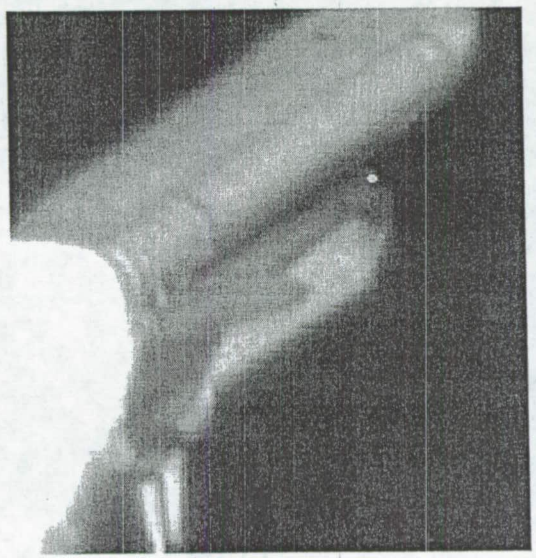
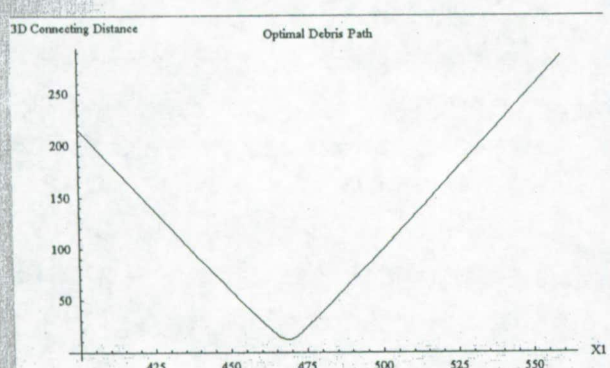
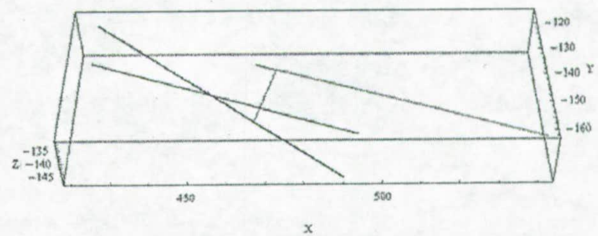


___ *E212 at 21.753 s*   ___ *ET208 at 21.757 s*   ___ *E212 at 21.769 s*





_______ *E212 at 21.753 s* _______ *E212 at 21.769 s*

_______ *ET208 at 21.757 s* _______ *Optimized path.*

Columbia Investigation: Foam Debris Detection/Location (Cont.)

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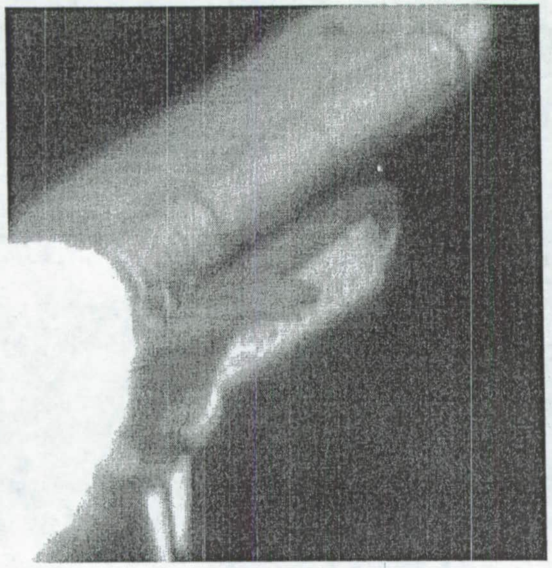
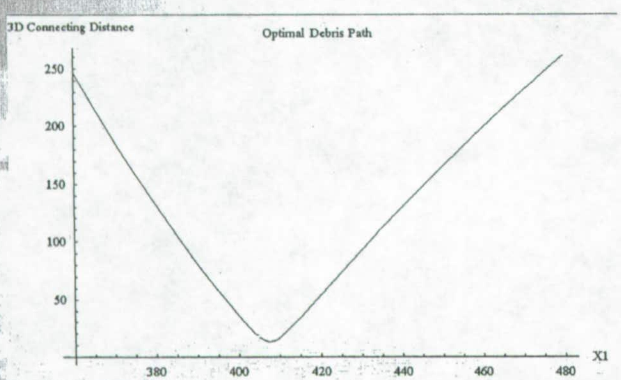
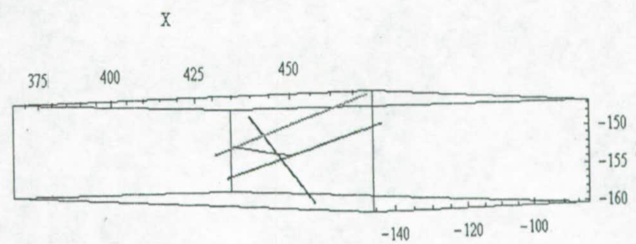
E212 at 21.722 s



ET208 at 21.724 s

E212 at 21.738 s





E212 at 21.722 s; E212 at 21.738 s; ET208 at 21.724 s; Optimized path.

Columbia Investigation: Foam Debris Detection/Location (Cont.)

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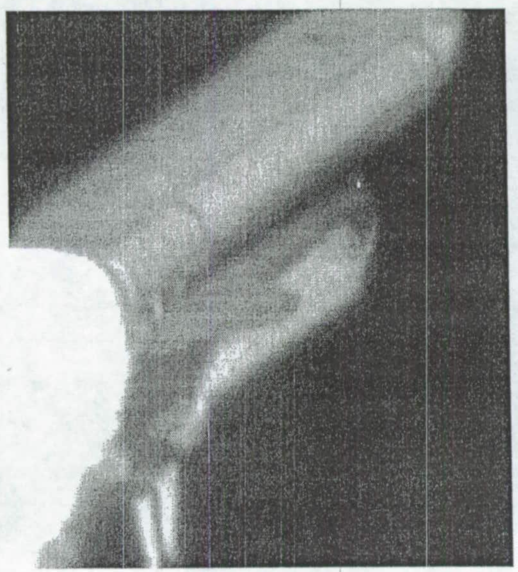
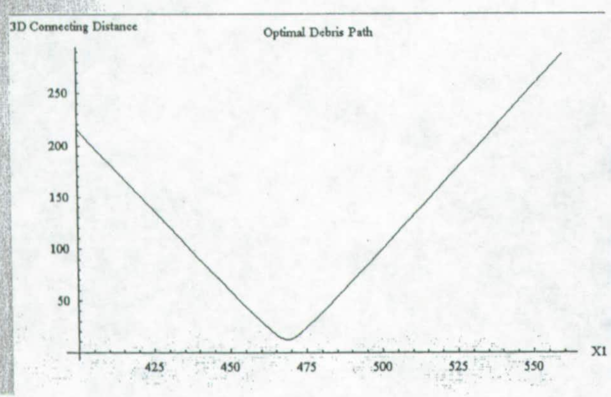
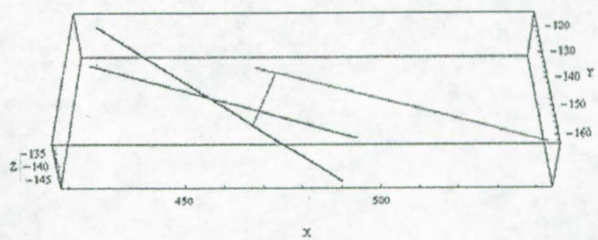
E212 at 21.753 s



ET208 at 21.757 s

E212 at 21.769 s





E212 at 21.753 s — E212 at 21.769 s

ET208 at 21.757 s — Optimized path.

Columbia Investigation: Foam Debris Detection/Location (Cont.)

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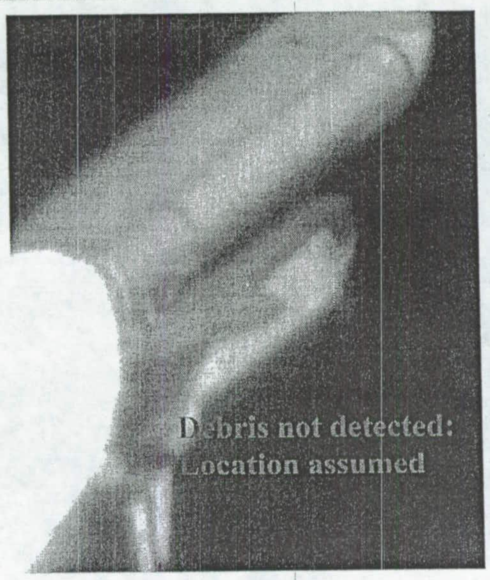
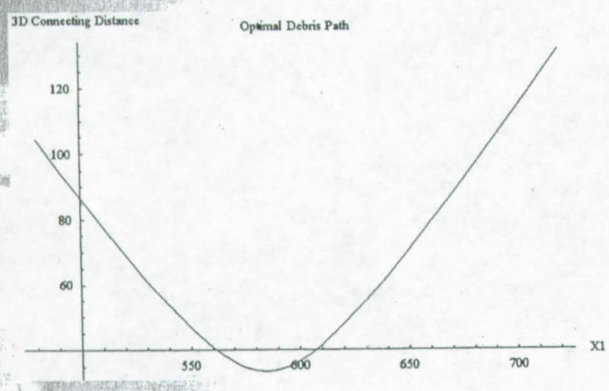
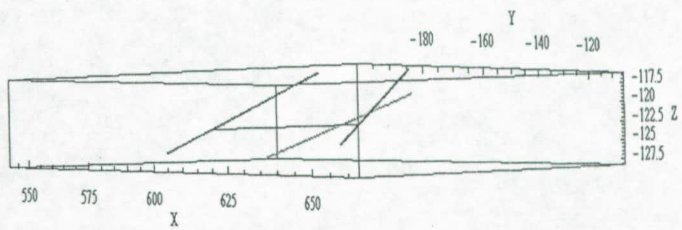


E212 at 21.784 s — ET208 at 21.791 s — E212 at 21.800 s





E212 at 21.784 s — E212 at 21.800 s

ET208 at 21.791 s — Optimized path.

Columbia Investigation: Foam Debris Detection/Location (Cont.)

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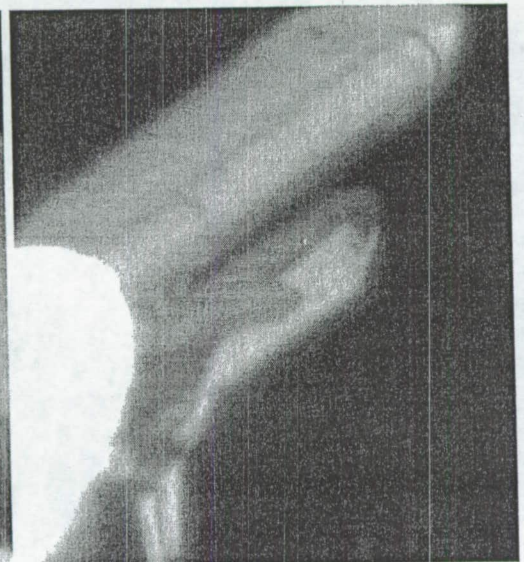
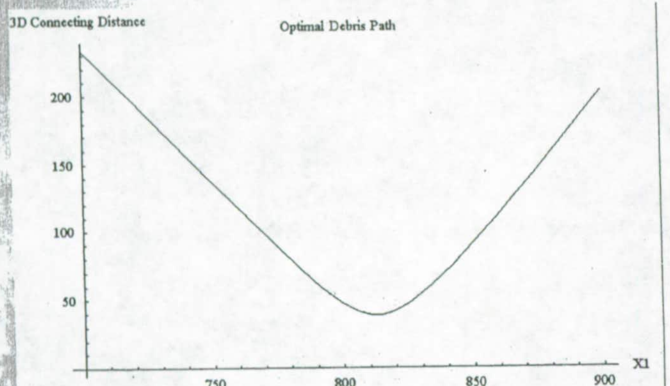
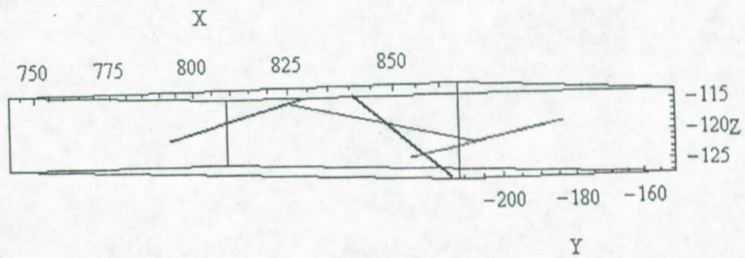
E212 at 21.816 s



ET208 at 21.824 s

E212 at 21.831 s





E212 at 21.816 s ***E212 at 21.831 s***

ET208 at 21.824 s ***Optimized path.***

Columbia Investigation: Foam Debris Trajectory

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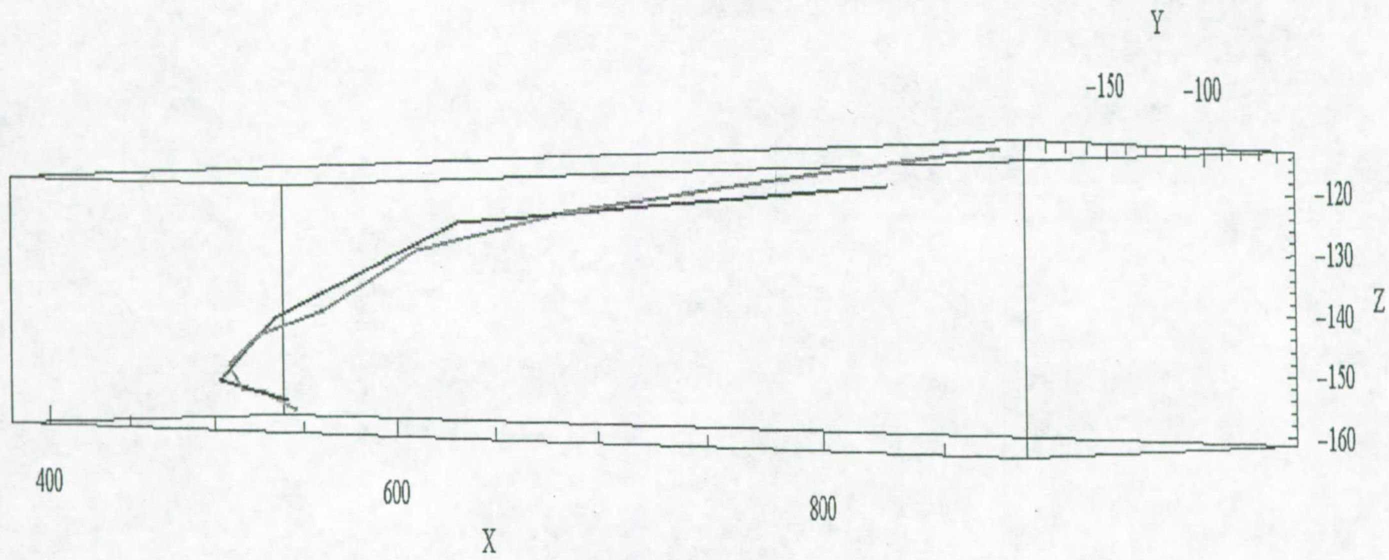

_______ **Current Work** _______ **Lane-Nelson work via LighWave3D**

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Columbia Investigation: Foam Debris Trajectory

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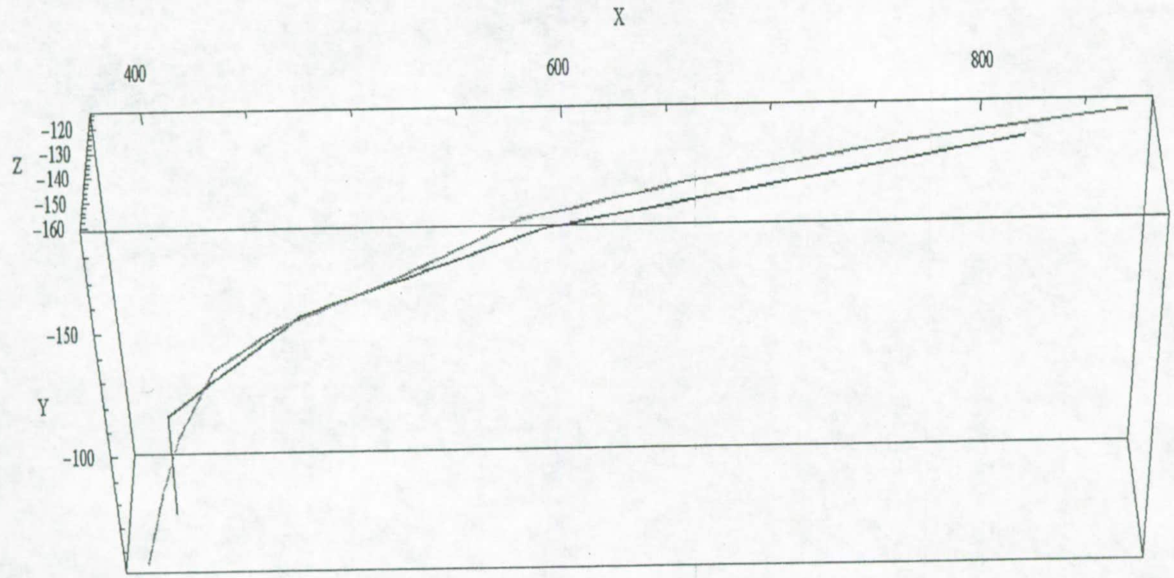

Current Work ______ Lane-Nelson work via LighWave3D

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Columbia Investigation: Foam Debris Velocity

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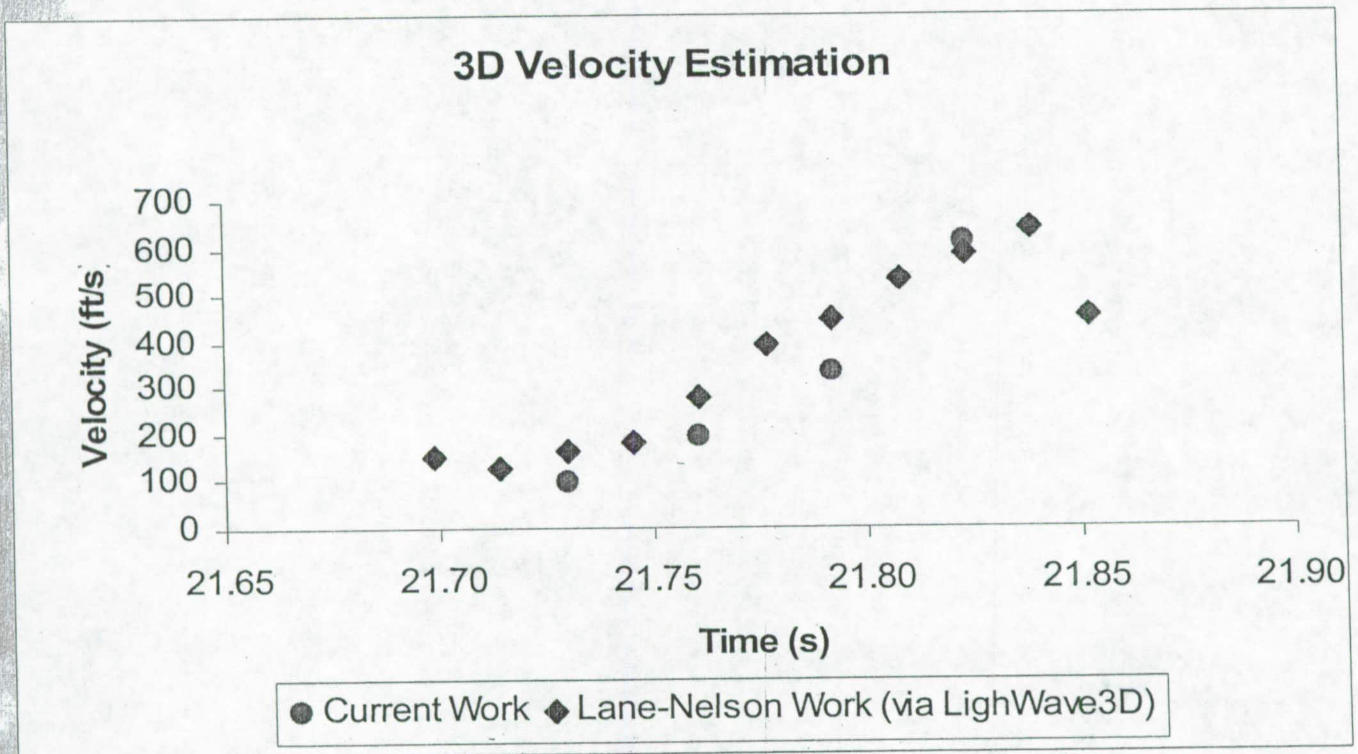

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Proposed Debris Analysis Software System Development at KSC

Kennedy Space Center

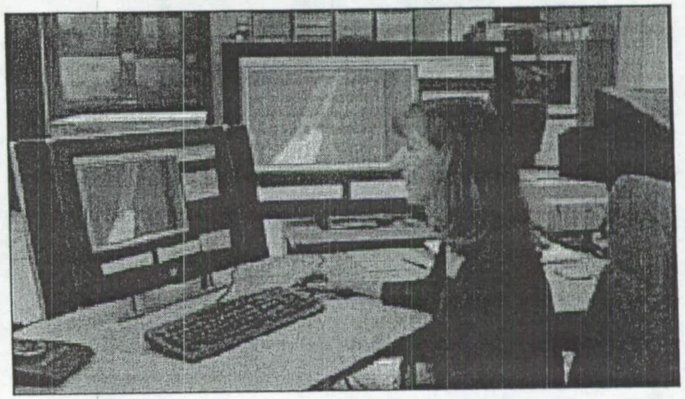
NASA

Automated Debris Detection at KSC VAB Launch Analysis Laboratory

sgi

Microsoft Windows

Current OS housing FRAT, FRED, SC-based image pattern recognition.



VAB Launch Analysis Laboratory at KSC equipped with recently acquired SGI Reality Center facility with a 7-foot display, and advanced SGI TP9500 data management subsystem.

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Commercialization: Licensing

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Kennedy Space Center

Patent

NASA KSC

Technology Marketing

RTI INTERNATIONAL

Research Triangle Institute (RTI)
Center for Technology Applications
PO Box 12194, 3040 Cornwallis
Research Triangle Park, NC 27709

NASA Technology Applications Team:

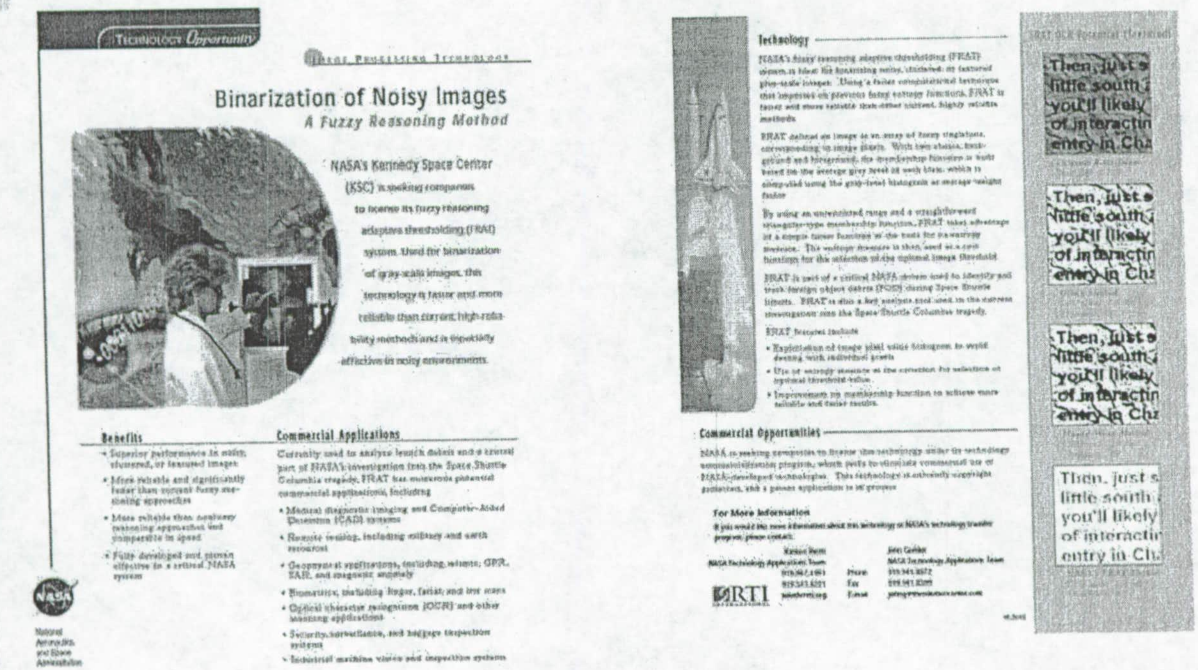
Kirsten Rieth
Phone: (919) 967-4991
Fax: (919) 541-6221
Email: krieth@rti.org

John Geikler
Phone: (919) 941-8372
Fax: (919) 941-8399
Email: johng@thesolutioncenter.com

Commercialization (Cont.)

ASRC Aerospace Corp.

Kennedy Space Center



Catalog

Figure 9

Commercialization (Cont.)

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http://nasa.rti.org/ksc/imaging

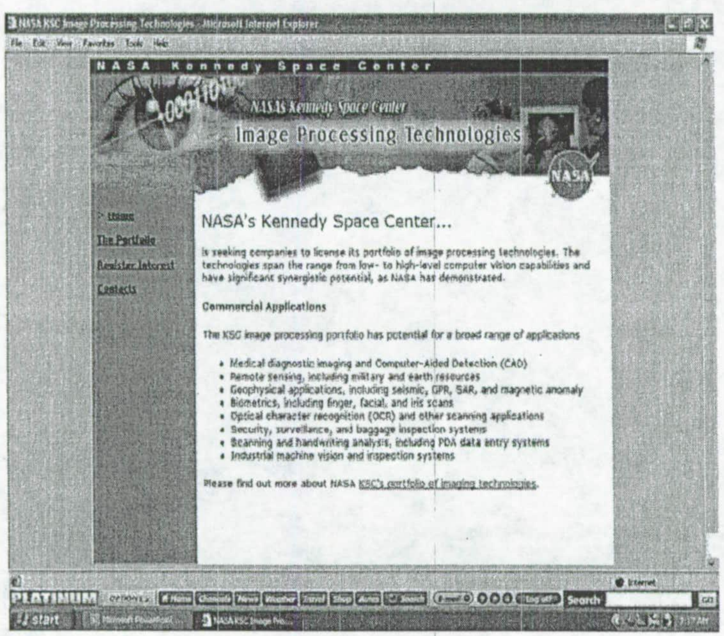

Figure 8

Commercialization (Cont.)

ASRC Aerospace Corp.

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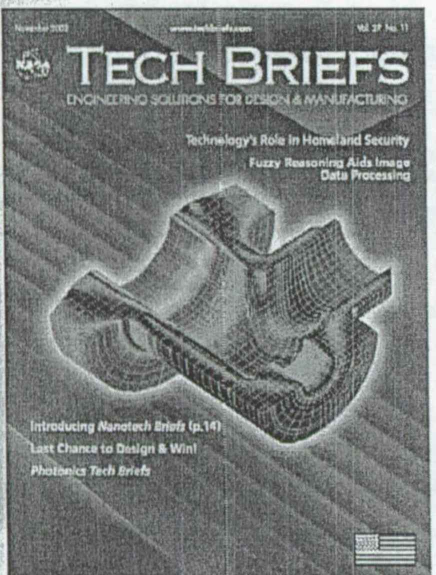


Detecting Edges in Images by Use of Fuzzy Reasoning

Human visual processing is partly imitated in order to harness some of its power.

John F. Kennedy Space Center, Florida

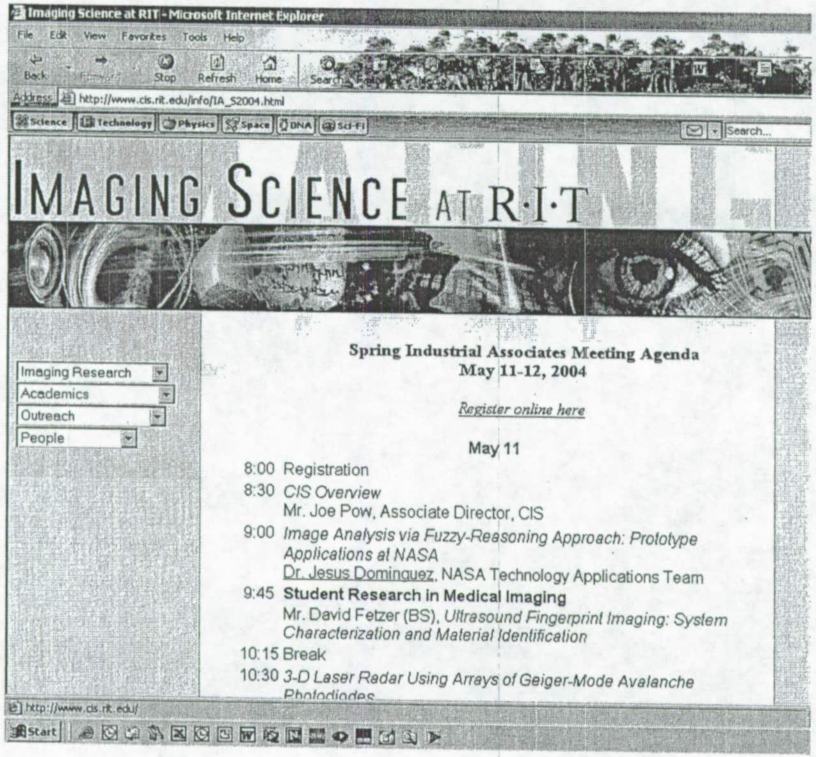
Software for Acquiring Image Data for PIV

John H. Glenn Research Center, Cleveland, Ohio

Commercialization (Cont.)

ASRC Aerospace Corp.

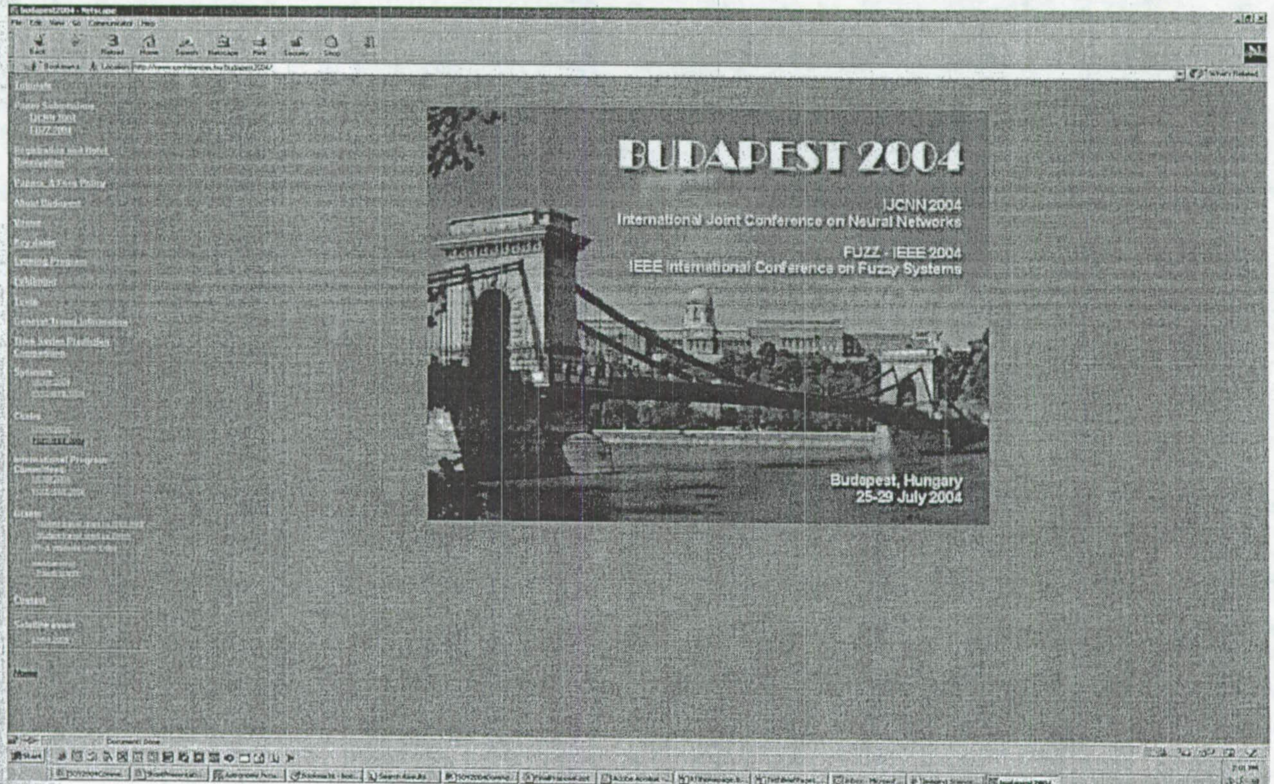
Kennedy Space Center



Commercialization (Cont.)

ASRC Aerospace Corp.

Kennedy Space Center



Commercialization (Cont.)

ASRC Aerospace Corp.

Kennedy Space Center